

# Chapter 2

## COMBINATIONS OF LOADS

### 2.1 GENERAL

Buildings and other structures shall be designed using the provisions of either Section 2.3 or 2.4. Where elements of a structure are designed by a particular material standard or specification, they shall be designed exclusively by either Section 2.3 or 2.4.

### 2.2 SYMBOLS

$A_k$  = load or load effect arising from extra ordinary event  $A$   
 $D$  = dead load  
 $D_i$  = weight of ice  
 $E$  = earthquake load  
 $F$  = load due to fluids with well-defined pressures and maximum heights  
 $F_a$  = flood load  
 $H$  = load due to lateral earth pressure, ground water pressure, or pressure of bulk materials  
 $L$  = live load  
 $L_r$  = roof live load  
 $R$  = rain load  
 $S$  = snow load  
 $T$  = self-straining load  
 $W$  = wind load  
 $W_i$  = wind-on-ice determined in accordance with Chapter 10

### 2.3 COMBINING FACTORED LOADS USING STRENGTH DESIGN

#### 2.3.1 Applicability

The load combinations and load factors given in Section 2.3.2 shall be used only in those cases in which they are specifically authorized by the applicable material design standard.

#### 2.3.2 Basic Combinations

Structures, components, and foundations shall be designed so that their design strength equals or exceeds the effects of the factored loads in the following combinations:

1.  $1.4D$
2.  $1.2D + 1.6L + 0.5(L_r \text{ or } S \text{ or } R)$
3.  $1.2D + 1.6(L_r \text{ or } S \text{ or } R) + (L \text{ or } 0.5W)$
4.  $1.2D + 1.0W + L + 0.5(L_r \text{ or } S \text{ or } R)$

5.  $1.2D + 1.0E + L + 0.2S$
6.  $0.9D + 1.0W$
7.  $0.9D + 1.0E$

#### EXCEPTIONS:

1. The load factor on  $L$  in combinations 3, 4, and 5 is permitted to equal 0.5 for all occupancies in which  $L_o$  in Table 4-1 is less than or equal to 100 psf, with the exception of garages or areas occupied as places of public assembly.
2. In combinations 2, 4, and 5, the companion load  $S$  shall be taken as either the flat roof snow load ( $p_f$ ) or the sloped roof snow load ( $p_s$ ).

Where fluid loads  $F$  are present, they shall be included with the same load factor as dead load  $D$  in combinations 1 through 5 and 7.

Where load  $H$  are present, they shall be included as follows:

1. where the effect of  $H$  adds to the primary variable load effect, include  $H$  with a load factor of 1.6;
2. where the effect of  $H$  resists the primary variable load effect, include  $H$  with a load factor of 0.9 where the load is permanent or a load factor of 0 for all other conditions.

Effects of one or more loads not acting shall be investigated. The most unfavorable effects from both wind and earthquake loads shall be investigated, where appropriate, but they need not be considered to act simultaneously. Refer to Section 12.4 for specific definition of the earthquake load effect  $E$ .<sup>1</sup>

Each relevant strength limit state shall be investigated.

#### 2.3.3 Load Combinations Including Flood Load

When a structure is located in a flood zone (Section 5.3.1), the following load combinations shall be considered in addition to the basic combinations in Section 2.3.2:

1. In V-Zones or Coastal A-Zones,  $1.0W$  in combinations 4 and 6 shall be replaced by  $1.0W + 2.0F_a$ .
2. In noncoastal A-Zones,  $1.0W$  in combinations 4 and 6 shall be replaced by  $0.5W + 1.0F_a$ .

<sup>1</sup>The same  $E$  from Sections 1.4 and 12.4 is used for both Sections 2.3.2 and 2.4.1. Refer to the Chapter 11 Commentary for the Seismic Provisions.

### 2.3.4. Load Combinations Including Atmospheric Ice Loads

When a structure is subjected to atmospheric ice and wind-on-ice loads, the following load combinations shall be considered:

1.  $0.5(L_r \text{ or } S \text{ or } R)$  in combination 2 shall be replaced by  $0.2D_i + 0.5S$ .
2.  $1.0W + 0.5(L_r \text{ or } S \text{ or } R)$  in combination 4 shall be replaced by  $D_i + W_i + 0.5S$ .
3.  $1.0W$  in combination 6 shall be replaced by  $D_i + W_i$ .

### 2.3.5 Load Combinations Including Self-Straining Loads

Where applicable, the structural effects of load  $T$  shall be considered in combination with other loads. The load factor on load  $T$  shall be established considering the uncertainty associated with the likely magnitude of the load, the probability that the maximum effect of  $T$  will occur simultaneously with other applied loadings, and the potential adverse consequences if the effect of  $T$  is greater than assumed. The load factor on  $T$  shall not have a value less than 1.0.

### 2.3.6 Load Combinations for Nonspecified Loads

Where approved by the Authority Having Jurisdiction, the Responsible Design Professional is permitted to determine the combined load effect for strength design using a method that is consistent with the method on which the load combination requirements in Section 2.3.2 are based. Such a method must be probability-based and must be accompanied by documentation regarding the analysis and collection of supporting data that is acceptable to the Authority Having Jurisdiction.

## 2.4 COMBINING NOMINAL LOADS USING ALLOWABLE STRESS DESIGN

### 2.4.1 Basic Combinations

Loads listed herein shall be considered to act in the following combinations; whichever produces the most unfavorable effect in the building, foundation, or structural member being considered. Effects of one or more loads not acting shall be considered.

1.  $D$
2.  $D + L$
3.  $D + (L_r \text{ or } S \text{ or } R)$

4.  $D + 0.75L + 0.75(L_r \text{ or } S \text{ or } R)$
5.  $D + (0.6W \text{ or } 0.7E)$
- 6a.  $D + 0.75L + 0.75(0.6W) + 0.75(L_r \text{ or } S \text{ or } R)$
- 6b.  $D + 0.75L + 0.75(0.7E) + 0.75S$
7.  $0.6D + 0.6W$
8.  $0.6D + 0.7E$

### EXCEPTIONS:

1. In combinations 4 and 6, the companion load  $S$  shall be taken as either the flat roof snow load ( $p_f$ ) or the sloped roof snow load ( $p_s$ ).
2. For nonbuilding structures, in which the wind load is determined from force coefficients,  $C_f$ , identified in Figures 29.5-1, 29.5-2 and 29.5-3 and the projected area contributing wind force to a foundation element exceeds 1,000 square feet on either a vertical or a horizontal plane, it shall be permitted to replace  $W$  with  $0.9W$  in combination 7 for design of the foundation, excluding anchorage of the structure to the foundation.
3. It shall be permitted to replace  $0.6D$  with  $0.9D$  in combination 8 for the design of Special Reinforced Masonry Shear Walls, where the walls satisfy the requirement of Section 14.4.2.

Where fluid loads  $F$  are present, they shall be included in combinations 1 through 6 and 8 with the same factor as that used for dead load  $D$ .

Where load  $H$  is present, it shall be included as follows:

1. where the effect of  $H$  adds to the primary variable load effect, include  $H$  with a load factor of 1.0;
2. where the effect of  $H$  resists the primary variable load effect, include  $H$  with a load factor of 0.6 where the load is permanent or a load factor of 0 for all other conditions.

The most unfavorable effects from both wind and earthquake loads shall be considered, where appropriate, but they need not be assumed to act simultaneously. Refer to Section 1.4 and 12.4 for the specific definition of the earthquake load effect  $E$ .<sup>2</sup>

Increases in allowable stress shall not be used with the loads or load combinations given in this standard unless it can be demonstrated that such an increase is justified by structural behavior caused by rate or duration of load.

<sup>2</sup>The same  $E$  from Sections 1.4 and 12.4 is used for both Sections 2.3.2 and 2.4.1. Refer to the Chapter 11 Commentary for the Seismic Provisions.

#### 2.4.2 Load Combinations Including Flood Load

When a structure is located in a flood zone, the following load combinations shall be considered in addition to the basic combinations in Section 2.4.1:

1. In V-Zones or Coastal A-Zones (Section 5.3.1),  $1.5F_a$  shall be added to other loads in combinations 5, 6, and 7, and  $E$  shall be set equal to zero in 5 and 6.
2. In non-coastal A-Zones,  $0.75F_a$  shall be added to combinations 5, 6, and 7, and  $E$  shall be set equal to zero in 5 and 6.

#### 2.4.3 Load Combinations Including Atmospheric Ice Loads

When a structure is subjected to atmospheric ice and wind-on-ice loads, the following load combinations shall be considered:

1.  $0.7D_i$  shall be added to combination 2.
2. ( $L_r$  or  $S$  or  $R$ ) in combination 3 shall be replaced by  $0.7D_i + 0.7W_i + S$ .
3.  $0.6W$  in combination 7 shall be replaced by  $0.7D_i + 0.7W_i$ .

#### 2.4.4 Load Combinations Including Self-Straining Loads

Where applicable, the structural effects of load  $T$  shall be considered in combination with other loads. Where the maximum effect of load  $T$  is unlikely to occur simultaneously with the maximum effects of other variable loads, it shall be permitted to reduce the magnitude of  $T$  considered in combination with these other loads. The fraction of  $T$  considered in combination with other loads shall not be less than 0.75.

### 2.5 LOAD COMBINATIONS FOR EXTRAORDINARY EVENTS

#### 2.5.1 Applicability

Where required by the owner or applicable code, strength and stability shall be checked to ensure that structures are capable of withstanding the effects of extraordinary (i.e., low-probability) events, such as fires, explosions, and vehicular impact without disproportionate collapse.

#### 2.5.2 Load Combinations

##### 2.5.2.1 Capacity

For checking the capacity of a structure or structural element to withstand the effect of an extraordinary event, the following gravity load combination shall be considered:

$$(0.9 \text{ or } 1.2)D + A_k + 0.5L + 0.2S \quad (2.5-1)$$

in which  $A_k$  = the load or load effect resulting from extraordinary event  $A$ .

##### 2.5.2.2 Residual Capacity

For checking the residual load-carrying capacity of a structure or structural element following the occurrence of a damaging event, selected load-bearing elements identified by the Responsible Design Professional shall be notionally removed, and the capacity of the damaged structure shall be evaluated using the following gravity load combination:

$$(0.9 \text{ or } 1.2)D + 0.5L + 0.2(L_r \text{ or } S \text{ or } R) \quad (2.5-2)$$

#### 2.5.3 Stability Requirements

Stability shall be provided for the structure as a whole and for each of its elements. Any method that considers the influence of second-order effects is permitted.